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Causes and Behavior of a Tornadic Fire-Whirlwind

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ABSTRACT: A destructive whirlwind of tornadic force was formed in a 600-acre brush fire burning on the lee side of a ridge near Santa Barbara on March 7, 1964. The fire whirlwind, formed in a post-frontal unstable air mass, cut a mile long path, injured 4 people, destroyed 2 houses, a barn, and 4 automobiles, and wrecked a 100-tree avocado orchard.

Normally an early March brush fire would not be much of a problem for experienced firefighters in the Santa Barbara area of the Los Padres National Forest in southern California. But the Polo fire of March 7, 1964, spread several times faster than expected and culminated in a fire-whirlwind of tornadic violence (fig. 1). It represents a classic case of such fire behavior and was unusually well documented by surface and upper air observations. This fire damaged 600 acres of prime watershed land, and the fire-induced tornado injured 4 persons; destroyed 2 homes, a barn, and 3 automobiles; and toppled almost 100 avocado trees.

BURNING CONDITIONS

FUELS

The fire area was predominantly 50-year old ceanothus (*Ceanothus* sp.) that stood 10 to 15 feet high (fig. 2). Minor amounts of California sagebrush (*Artemisia californica*) and scrub oak (*Quercus dumosa*) were intermixed with the ceanothus. About a third of the fuel was dead brush; much of it probably died from lack of water during the past 15 years. Twelve of these 15 years have been periods of below normal rainfall in southern California. As Buck (1948) has shown, moisture shortages reduce the amount of new plant growth and increase the quantity of dead material--boosting the fire danger. Such shortages have a cumulative adverse effect on fuel characteristics (Pirsko 1962). Up to the time of the Polo fire the precipitation year was dry (fig. 3).

There was very little understory in the more dense ceanothus. Toward the bottom of the slope, grass that covered open areas was about 95 percent dead. The gentle slope at the base of the ridge supported lemon and avocado orchards.

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Photo courtesy Santa Barbara News-Press

Figure 1.--Bursting out with tornadic violence, the Polo fire of March 7, 1964, represents a classic case of extreme fire behavior.

Figure 2.--Dense ceanothus stand at edge of fire area.

Moisture content of the green brush was probably only slightly below normal for March. Three days after the fire, samples of living brush collected from an adjacent area typical of the burned area showed:

Fuel:	Average moisture content (percent)
Ceanothus	103.5
California sagebrush	166.0
Scrub oak	75.4

The amount of moisture was determined by the xylene distillation method (Buck and Hughes 1939). Such a range of moistures is only slightly below the average for southern California at that time of the year. Moisture content of dead brush was shown by a fuel stick reading of 8.5 percent at noon on the day of the fire at the nearest fire danger station, Los Prietos, 13 miles to the northwest.

TOPOGRAPHY

The fire burned on the south side of a 2-mile long hogback ridge at the foot of the Santa Ynez Mountains (fig. 4). The hogback, 1,100 feet high and about 3/4 of a mile wide at the base, drops off at its east end into a V-shaped canyon, the Arroyo Paredon (Oil Canyon) (fig. 5). To the east of the canyon a hill about 1,000 feet high accentuates this notch.

Southward from the toe of the ridge the terrain slopes gently toward the ocean a half-mile away. North of the hogback, the Santa Ynez Mountains rise steeply to 3,500 and 4,000 feet, within 4 to 6 miles of the coastline. Slopes as steep as 100 percent are common.

The topography and drainage patterns are conducive to eddying, turbulent winds (Graham 1952, 1957).

GENERAL WEATHER

A strong, persistent high pressure cell (1,038 mb.) continued over the eastern Pacific, from 35° to 40° N. and W., before and during the fire. A low pressure trough extended from coastal southern California eastward to and beyond the Rocky Mountain region from March 5 to 7. During this period, air movement down the west side of this trough kept southern California unseasonally cool.

Two days before the fire, on March 5, a dry cold front surged southward from central to southern California. A day later, a second cold front moving southward from the San Francisco region brought showers to the Tehachapi Mountains south of Bakersfield. Fresno reported thunderstorms.

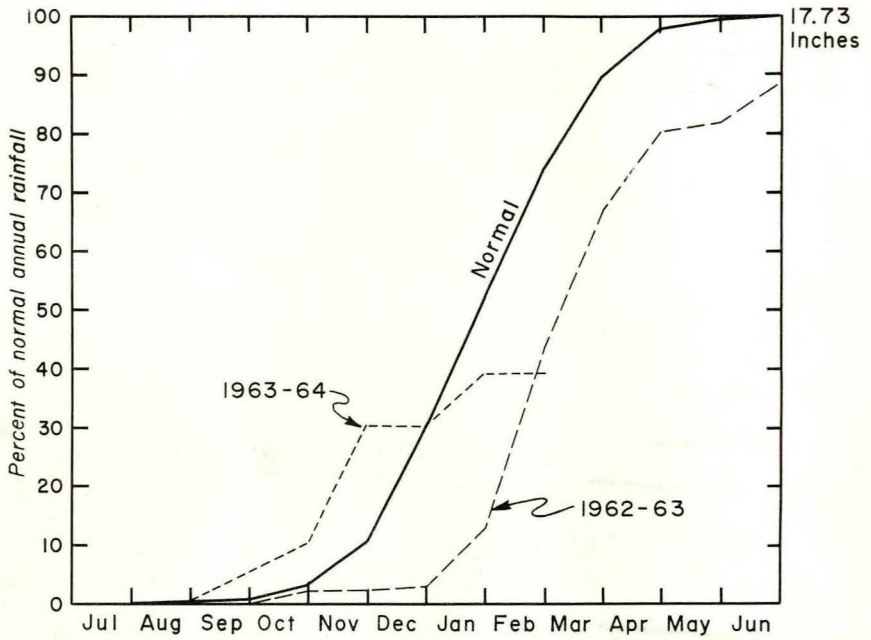


Figure 3.--Last two years' precipitation compared to normal at Santa Barbara.

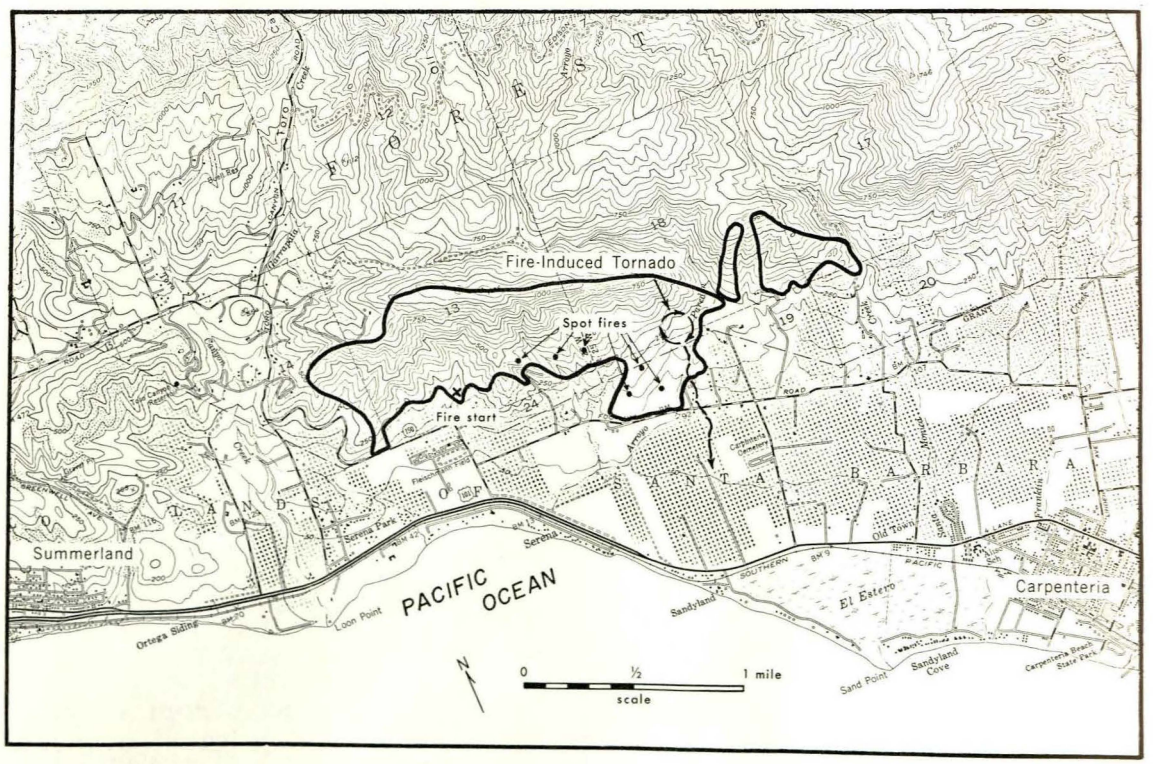


Figure 4.--Location of Polo fire.

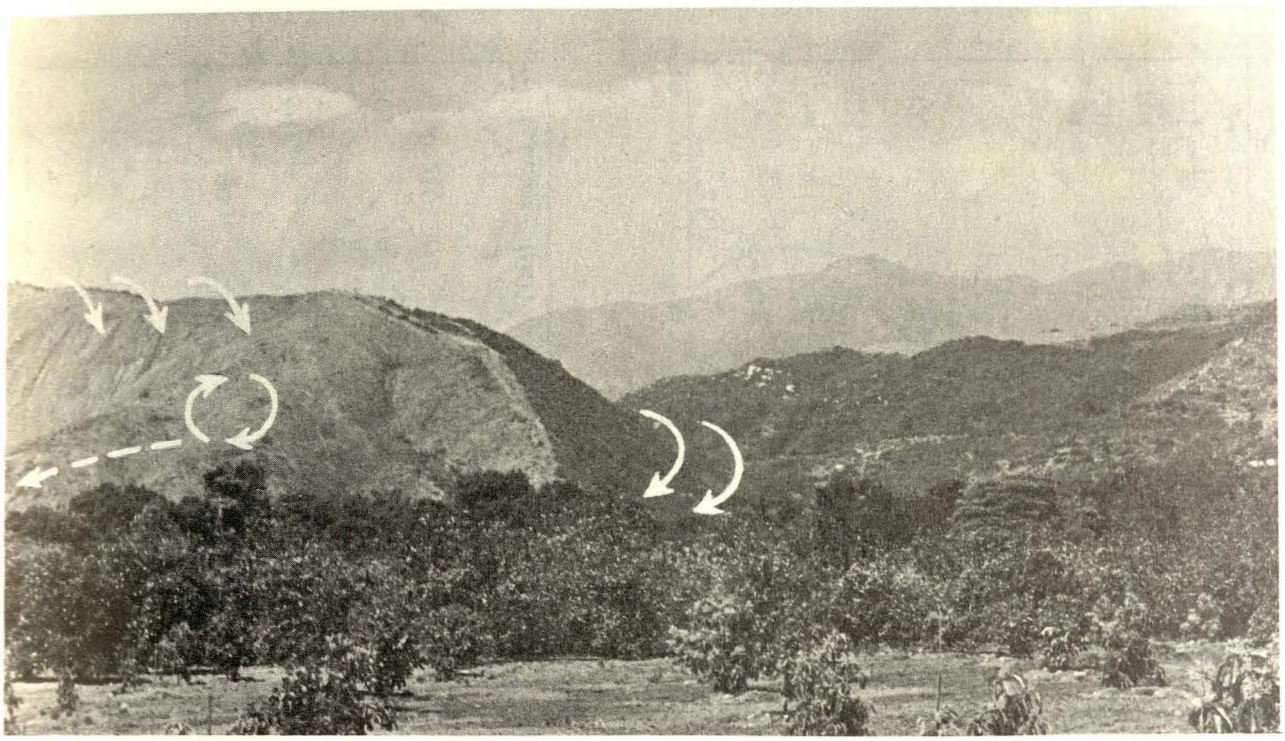


Figure 5.--V-shaped Arroyo Paredon emerging from behind burned ridge.

On the day of the fire, March 7, cold air swept into the Santa Barbara area behind the front. Surface maps for the preceding 24 hours show the development of the air mass through California (fig. 6). Upper level maps at 1600 p.s.t. revealed a cold air mass covering most of Utah, Nevada, and California (fig. 7). North component winds were strongest over California at all levels. Scattered clouds formed around 1000 p.s.t. in the general area and became broken two hours later. Towering cumulus and cumulo-nimbus clouds were reported west and southwest of Santa Barbara from 0700 to 1600, March 7. After 1300, towering cumulus was also reported to the north; clouds were never directly over the fire area. The Catalina weather radar located cumulus activity in the San Rafael Mountains north of Santa Barbara during the fire.

Another indicator of instability is a comparison of the dry adiabat from the maximum surface temperature to the upper air sounding. The adiabat from the 60° F. temperature at Santa Barbara intersected the sounding at 10,000 feet and indicated instability to that altitude.

Jet streams at 300 mb. (30,000 feet) suggested instability at high levels. One jet from the north pivoted off the coast of southern California and moved to the northeast (fig. 8). A second jet from the southwest cut across the middle of lower California. Schaefer (1957) calls this type a conflict jet stream, and he suggests that a zone between streams is conducive to blow-up fires.

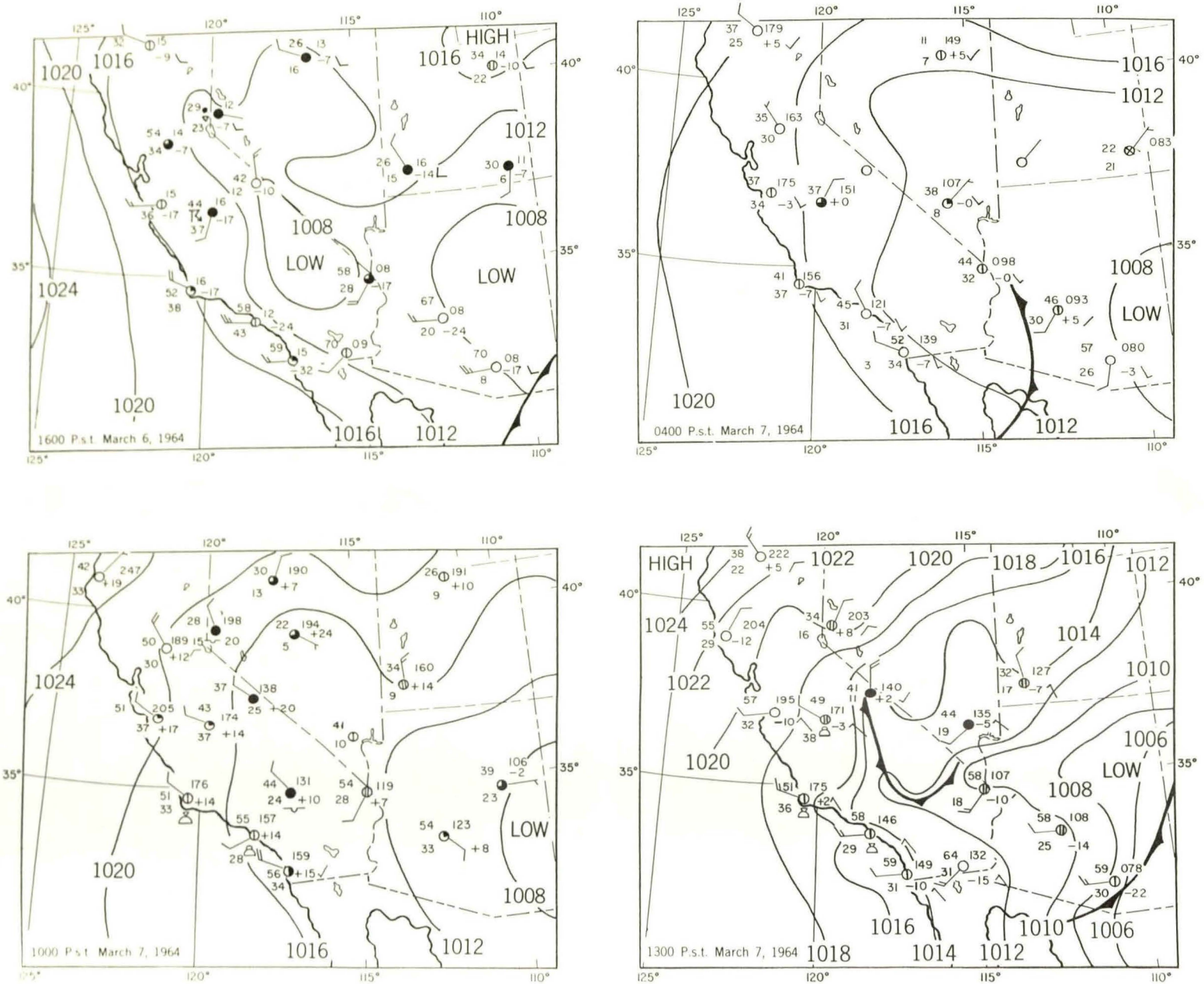


Figure 6.--Surface weather for southwestern United Sta preceding Polo fire. Last of two fronts moved through San Barbara area on March 6.

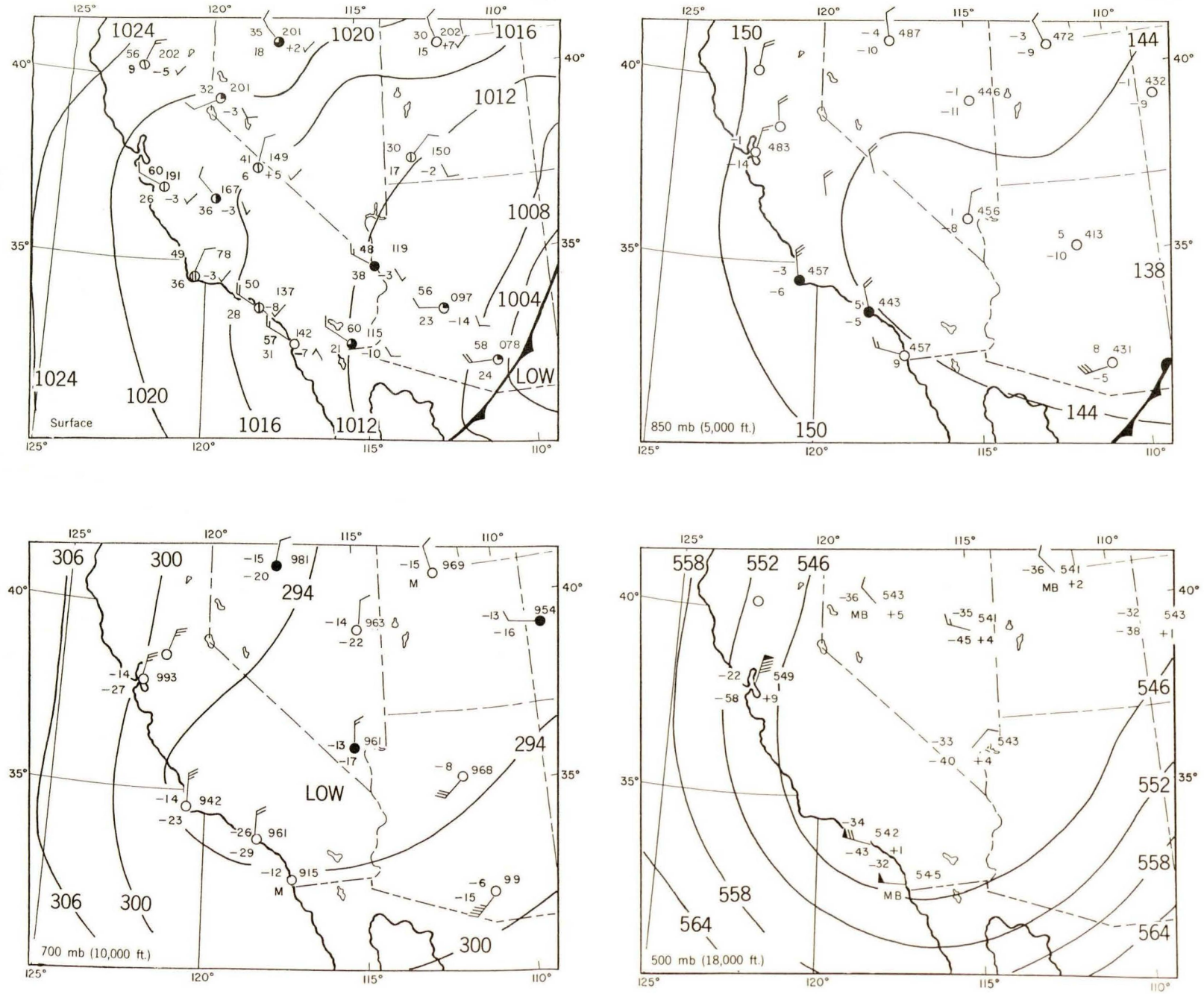


Figure 7.--Weather maps for 1600 p.s.t., March 7, 1964, the time of the Polo fire.

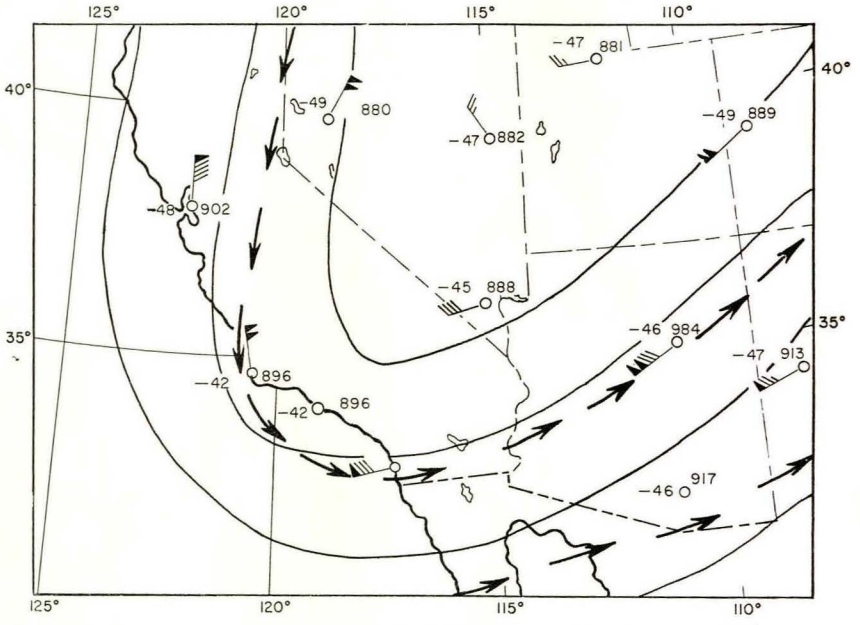
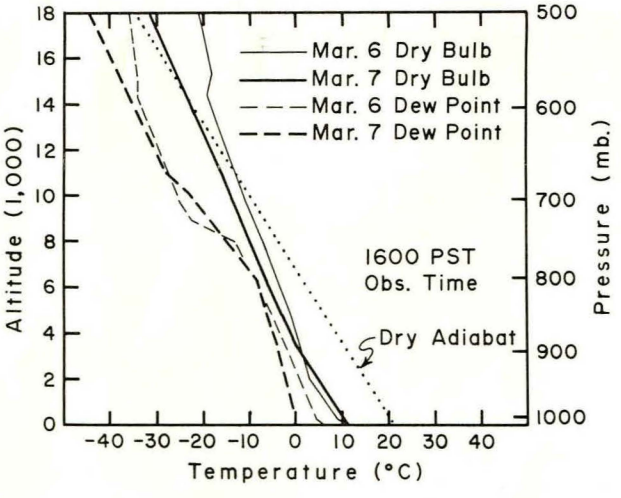


Figure 8.--Jet streams at 30,000 feet, 300 mb., 1600 p.s.t., March 7, 1964.


Mar. 6 Dry Bulb
Mar. 7 Dry Bulb
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Obs. Time
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Altitude (1,000)
Pressure (mb.)
Temperature (°C)
-40 -30 -20 -10 0 10 20 30 40
0 2 4 6 8 10 12 14 16 18
500 600 700 800 900 1000

Figure 9.--Upper air soundings--Point Arguello.

LOCAL WEATHER

On the ground, weather in the Santa Barbara area on Saturday morning, March 7, started out with clear skies and light westerly winds. Around 1000, scattered clouds developed, wind increased speed and shifted to the northwest. Cloud cover increased to broken clouds between noon and 1600. The wind speed increased in midafternoon at Santa Barbara to 18 miles per hour with gusts to 29. At sundown, skies started to clear and winds again became light west to northwesterly.

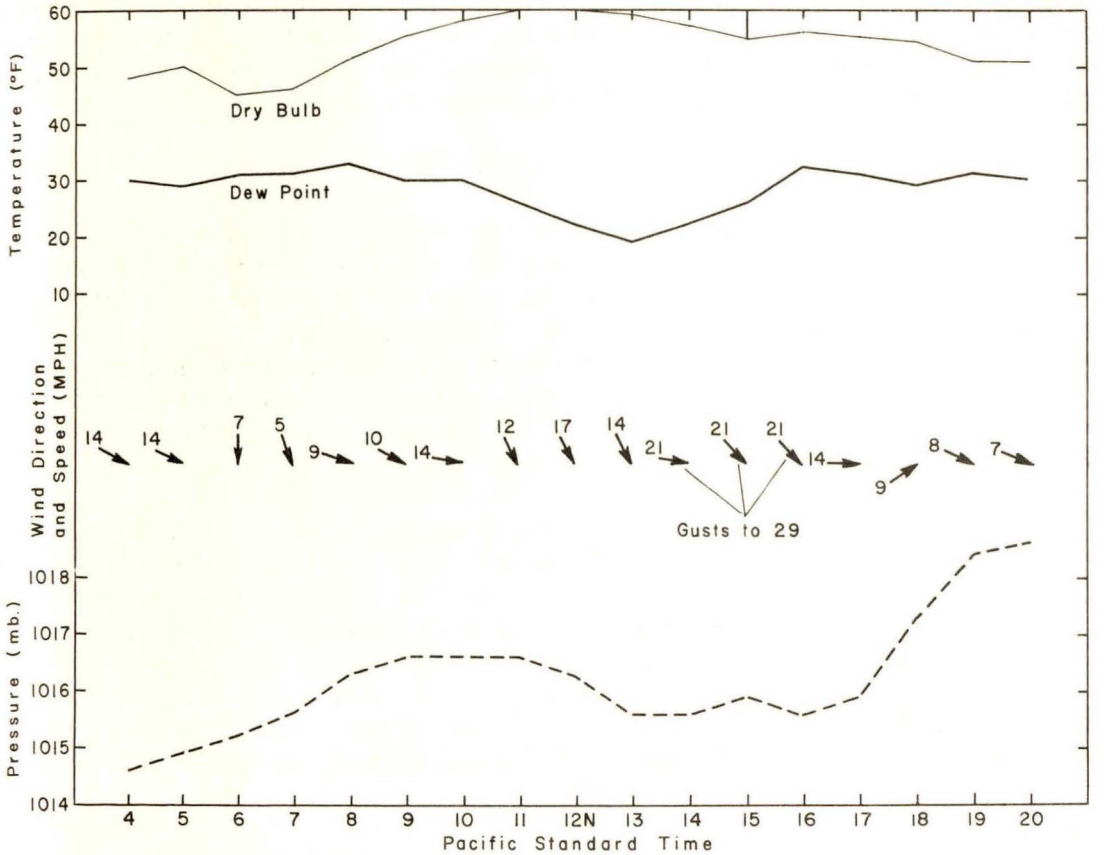

Figure 10.--Weather at Santa Barbara on March 7, 1964.

These conditions resulted from the cold front that earlier passed through the area. The 0400 p. s. t. upper air sounding at Point Arguello, 50 miles to the west, showed a deep influx of cold air. By 1600 p. s. t. the condition represented by the sounding was typical of those some distance behind the front (fig. 9). Above 550 mb., the frontal zone was indicated by the stable layer. Above 600 mb., the drying out was a result of subsidence in the cold air as it moved south (Krumm 1959). This subsidence moved downward to 900 mb. 24 hours later.

Surface winds in the Santa Barbara area were from the west to north-northwest (fig. 10). They were gentle in the morning, but became stronger during the afternoon. From 1400 through 1600 p. s. t. the wind averaged 21 miles per hour with gusts to 29. This was a quartering downslope wind in the fire area (fig. 11). Air temperatures ranged from 55 to 60 degrees. Dew point temperatures rose during the fire from 20 degrees to 32 degrees. Sea level atmospheric pressure was relatively constant at 1015.6 to 1015.9 mb.

If more clouds had drifted over the fire area, then the fire whirlwind might have been a tornado of the Pacific Coast type described by

Fawbush and Miller 1954. Nearly all the necessary conditions were present: a conditionally unstable lapse rate, cold moist air, scattered thunderstorms, slow change in weather sequence, and a low height of the freezing level above the terrain. No clouds were directly over the fire, however, and the funnel formed at the surface and moved upward rather than dropping down from above.

FIRE ACTION

About 1230 p. s. t. a high voltage transformer shorted at an irrigation pump house, creating a very hot ignition source. The resulting brush fire spread uphill against the gradient wind but under the influence of eddies on the lee side. Near the top of the hill, the fire began to turn east. Major forward progress was by spot fires that jumped as much as a quarter mile ahead of the front. An experienced fire control officer on the scene estimated that because of the spotting, forward spread to the east was about 10 times faster than normal for this area.

The fire approached Arroyo Paredon one mile east from the pump house around 1400 to 1430 p. s. t. As the main fire and spot fires joined near the Arroyo, many small whirlwinds were seen to start. Wind sweeping southward down Arroyo Paredon whirled clockwise to the west where the slope flattened out. In the unstable air vertical development was unhindered. Many more spot fires started as entire burning bushes, 5 to 10 feet tall, were carried aloft and dropped into unburned vegetation. These fires built up great quantities of heat. Whirls continued to form, rise, and break off at the top. Firefighters could hear the roar of shock waves from the intensely burning brush. Then many of the small whirls seemed to coalesce, and the whole fire area started to rotate clockwise.

This massive fire-bearing whirlwind built up in height and started to roll downslope to the south. It plucked brush and small oak trees from the ground and carried them aloft. The intense whirl continued its vertical growth. The southward movement steered the fire into the area of homes, a chicken ranch, and avocado orchards. That the whirl carried fire for about 200 feet after leaving the wildland fuel was shown by scorched and burned avocado trees and burned chickens at the ranch.

As it passed the ranch, the fire whirl ignited some walls. Eggs stacked for shipment were cooked in their crates. The whirlwind then sheared off the roof of a 7-room house, blew many windows inward, and lifted venetian blinds over the tops of the remaining walls. Streaking through the avocado orchard, the whirl tore some trees out of the ground, broke the tops of some, and smashed others (fig. 12). Limbs and trunks in its path pointed in the direction the fire whirl traveled. A 4-foot-diameter oak tree was uprooted and twisted toward the center of the path.

Four people were injured by flying material and falling debris. Two houses were destroyed--one of 2 stories and 10 rooms; three automobiles were smashed; and a garage and part (section) of the chicken ranch were blown apart. A barn filled with hay was hoisted in the air,

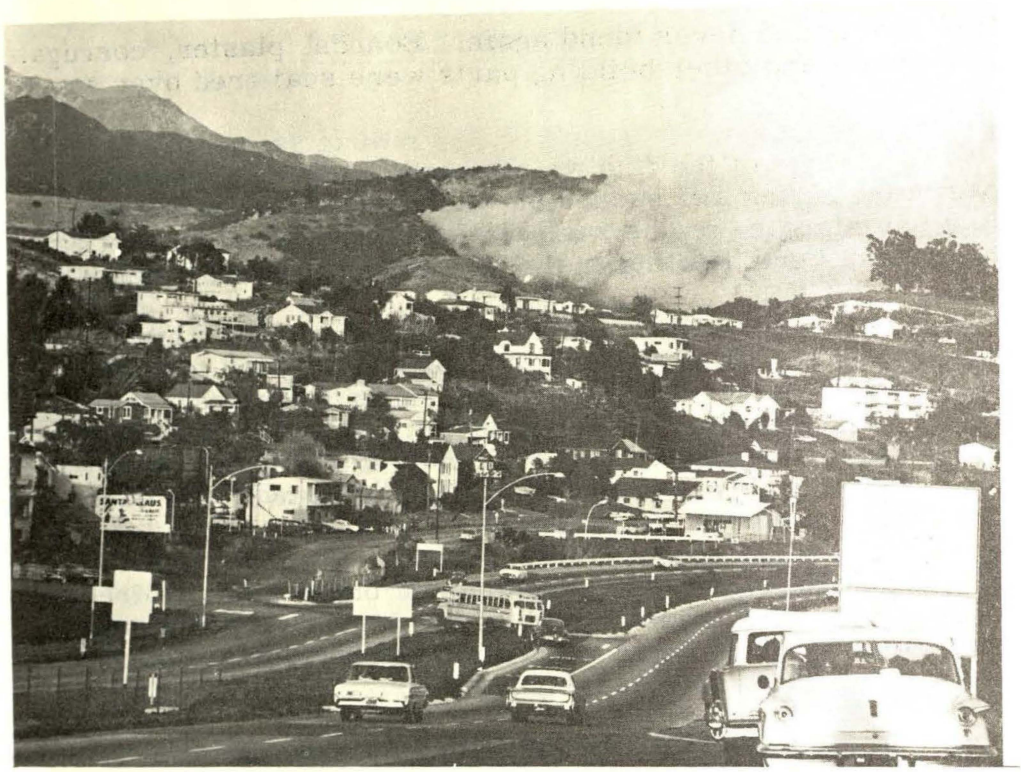

Photo courtesy Santa Barbara News-Press

Figure 11.--Smoke in early stages of fire showed prevailing downslope winds.

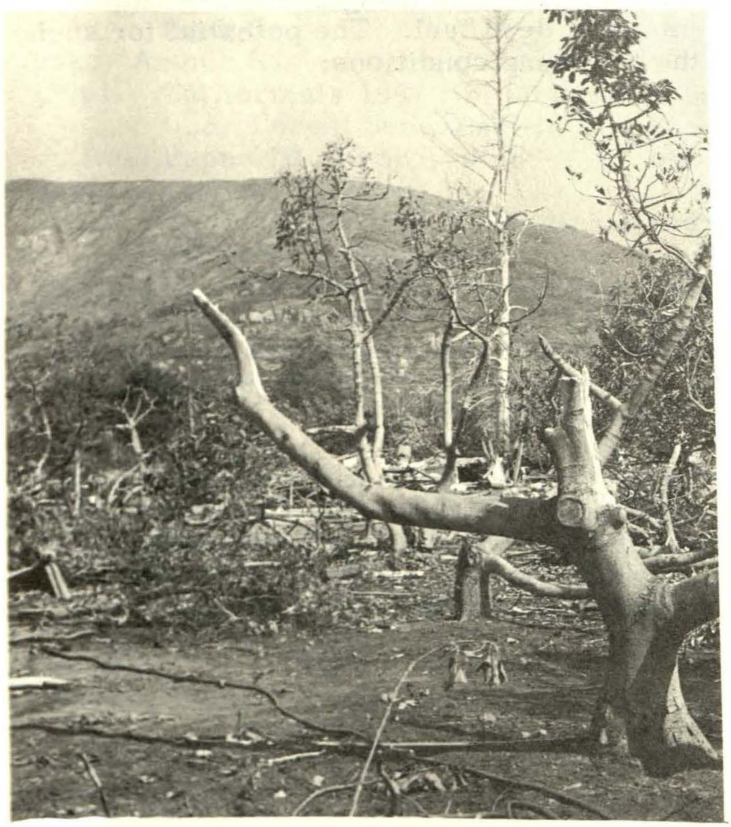

Figure 12.--Avocado orchard destroyed by intense whirlwind.

pulled apart, and never found again. Boards, plaster, corrugated sheet metal, and other building parts were scattered over an extensive area.

The fringe of the fire whirl passed over a Carpenteria fire department tanker and sucked out the rear window of the truck cab. A fireman standing on the rear platform was pulled up vertically so that his feet were pointing to the sky while his hands clasped the safety bar.

Continuing south through the avocado orchard to a two-lane road, the whirlwind turned at a right angle to the east for about 250 feet and then made another right angle turn to the south down an orchard lane. It rammed a 3-by 6-by 1/4-inch piece of plywood 3 inches deep into an oak tree, then lifted and moved overland to the south toward the Pacific Ocean.

At the main fire, the ridgetop fuel-break and the direction of the prevailing wind made control of the north fire perimeter comparatively easy. Two spot fires on the next ridge to the east were controlled by 2200 the same day.

FIRE BEHAVIOR LESSON

This intense fire whirl represents a classic case of extreme fire behavior. The high moisture content in the living fuels had no deterrent effect on fire behavior under existing unstable weather conditions and high percentage of dead fuel. The potential for such fire whirls exists under the following conditions:

- Unstable air
- Lee side of a ridge
- Moderate winds
- Large heat source

Spotting shortly after the start of the fire was an early indicator of instability and potential trouble (Bryam 1954; Byram and Martin 1962). Control action on the fire showed that this danger was recognized early. Forces were deployed on the flanks--a safer approach than a direct frontal attack on the head of the fire.

When and where such extreme behavior will take place is difficult to predict precisely. But southern California firefighters should be aware of the combination of fuels, topography, and weather that can trigger fire whirls of tornadic force. Allowances for this possibility must be made a part of the individual fire safety plan.

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